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Machinability Studies of Aluminium-based Hybrid Metal Matrix Composites – A Critical Review

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Abstract: *Aluminium composites are being used in many industries like automobiles, aeronautical, signage, cabinetry, cladding and transportation. Aluminium has a lightweight, long lasting, weather resistance, fire resistance and ratio of strength- to- weight is high properties. In today's rapidly developing manufacturing industries, there are many challenges to use metal composites. Also, there is a need to do research on various input parameters, safety parameters and environmental impacts. now, today's era vehicle manufacturing companies are growing up faster. vehicle manufacturing companies are focusing on increasing speed and reducing weight of vehicles so it will be achieved by choosing appropriate metal compositions. For the machining process, a turning operation has been selected. As the material hardness increases cutting forces increase and there is a need to select proper material to cut these composites. For preparing various metal composites stir casting, sand casting, squeeze casting, in-setu method and powder metallurgy process were used. The aim of this study is to give better suggestions and understanding of which material composites should be used? What is the alternative metal by considering operating conditions for machining and performance parameters? Present study is being investigated considering cutting speed, feed rate and depth of the cut while machining and how it affects performance parameters such as high tool wear, hardness, strength, SR, castability and chips production etc. Suggested carbon fibre is an alternative and how it affects the motion of an object and how it adds value in safety by considering certain parameters.*

Keywords: Reinforcement, Carbon fibre, Composites, Stir casting

I. INTRODUCTION

Aluminium based MMCs have been being used in the manufacturing industries widely. "Aluminium is at once as white as silver, as incorrigible as gold, as tenacious as iron, as fusible as copper, and as light as glass. "Mostly we use Aluminium in the aerospace and automobile industry due to its feasible properties like easy extrusion and processing, high production efficiency, lightweight, durable and robust, high strength to weight ratio. Among the lots of metal composites aluminium composites are meeting industrial needs. Weight exert force directly on an object due to gravity so the weight of the object affects the motion of the object. Higher weight required more forces to start and stop the object so minimizing weight is the challenging task in front of manufacturing industries. In the car manufacturing industries, the focus area is increasing the speed of the vehicle so we required a minimum inertia for it. For the future scope, flying cars can be implemented successfully in the upcoming years so as keeping in mind safety factors and mid-air collision we should use lightweight, high strength and thermal resistance material composites as seeing future risk we should prepare for carbon fibre. On carbon fibre more study should happen. We can use carbon fibre in light weight and highly risky applications such as aerospace, automotive and construction of bridges. Not much research has been done on the addition of the carbon fibres reinforcement. There are lots of research gaps for excellent atomic structure development material. with a minimal increase in density over the base alloy. The superior mechanical properties achieved by the reinforcement in MMCs, on the other hand, significantly influence their "machinability". This term which de- scribes the operational characteristics of a cutting tool in machining a material is rather ill-defined and is normally judged in terms of tool life, surface finish and power required for material removal [3]. Work piece variable

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comprises material hardness and various mechanical properties. It is very challenging to consider all factors affecting surface roughness for a certain manufacturing procedure. In a turning, it is the vital task to choose turning factors to attain high quality performance and maximize tool life [6]. There is not much work related to turning of in-situ based MMCs [10]. There are many non-conventional methods of machining viz. EDM; where surface roughness as well as topography of various alloys can be found out [17].

II. LITERATURE REVIEW

Johny james et.al.,[1] aimed to develop a hybrid metal matrix composite with 10% SiC and 5% TiB2 reinforcements using the AL6061 as a base metal using the stir casting method. the effects of the reinforcement percentages on the microstructure, hardness, strength, wear resistance, and surface roughness of the composite. Machining the composite proved challenging due to its hardness and abrasive nature, while it's leading to increased tool wear and poor surface finish being cutting speed 120m/min, feed rate 0.3mm/rev, depth of cut 0.5mm. The high tool wear and hardness were the performance parameters. Come to know, the author does, at the end, the addition of 10% SiC increased the strength by 20%, while the addition of 0-5% TiB2 decreased the strength by 50-60%. However, TiB2 improved the wear resistance of the composite.

senerkarabulut et.al.,[2] theirs study investigated the impact of machining parameters on surface quality of aluminium 7039-based metal matrix composites containing 10% SiC and 10%B4Cp. The experiments were designed using Taguchi's L18 (21 × 32) mixed orthogonal array, and the optimal cutting parameters were determined using S/N ratio and regression analysis. Used an uncoated carbide tool under dry cutting environment. By accepting an input argument as cutting speed 488m/min, feed rate 0.1mm/rev, depth of cut 1.3 mm and performance parameter were strength, fatigue resistance, tensile strength corrosion resistance. The study found that cutting speed and feed rate were the most significant factors affecting surface quality, while cutting depth had no significant correlation. Response surface plots were generated using a developed RSM model in MINITAB 16 software. At the end, it is revealed to the author what they needed to know that, SiC particles were homogeneously dispersed in the matrix structure. Due to the bonding effect of reinforcement particles, better surface quality was obtained during milling of AA7039/B4C as compared to AA7039/SiC.

J.T Lin et.al.,[3] studied the machinability of a DURALC composite, which is an aluminium alloy reinforced with 20 vol.% silicon carbide particles having A359 or A350-900 base metal. For experiment used 25 mm PCD inserts. The cutting conditions were, cutting speed 300, 500, 700m/min, feed rate 0.1, 0.2, 0.4 mm/rev, depth of cut 0.5 mm and side cutting edge angle 0 degree. By considering the performance parameter of the material removal rate, surface finishing, tool wear, strength, hardness and thermal resistance. the author comes to know at the end. the Taylor equation was modified to include volume removal. Surface finish worsens with increased feed rates, but not significantly with changing cutting speed. Tool life varies with speed, feed, and depth of cut. Proper operating conditions should be chosen based on practical applications.

M.Ramulu et.al.,[4] examined the drilling of Al2O3 aluminium-based metal matrix composites using various drills. while Machining MMC had to faced many challenges such as tool wear, high drilling forces, and burr formation. To address these challenges, diamond-coated tools and genetic algorithms were utilized to enhance tool life and optimize drilling conditions. For cutting rod values considered as cutting speed 1320, 2230, 3500, 5440 rpm, feed rate 0.0635, 0.1270, 0.1905 mm/rev. The performance parameter considered as drilling forces, surface finish, tool wear, and drilled-hole quality. Finally, the author found that, lower feed rates increased flank wear, while higher feed rates induced greater forces. Based on the research, PCD drills were recommended for finishing machining under most cutting conditions. On the other hand, HSS drills induced the highest drilling forces, while carbide-tipped drills produced undesirable continuous chips.

Ajithkumar J.P et.al.,[5] This study examined the impact of feed rate and tool coating on the surface roughness of three hybrid composites (Al7075-10%SiC-0.1% B4C, Al7075-10%SiC-0.1% Graphene, and Al7075-10%SiC-0.1% CNT) during dry turning. Results indicated that feed rate was the most significant factor affecting surface roughness, with a lower feed rate resulting in lower roughness values. for this kept cutting speed 50, 70, 90m/min, feed rate 0.1, 0.2, 0.3mm/rev, depth of cut 0.5,1, 1.5 mm. after machining process Graphene composite showed the lowest roughness among the three composites. The depth of cut had been observed the most significant influence on cutting forces, with graphene and CNT composites wanted higher forces than the B4C composite. The study employed Taguchi L18 orthogonal-array for experimental setup. For this study accepted performance parameters are cutting force, surface roughness. At the end author comes to know that, addition of graphene-based composites showed an improved surface roughness.

Rajesh Kumar bhushan et.al.,[6] added in the study to get results for the surface methodology and concurrent optimization system to determine the optimal cutting parameters for improved surface roughness and tool life in the turning of AA7075 with 10% SiC composites. Had considered the input parameter as cutting speed 90, 120,210 m/min, feed rate 0.15, 0.2, 0.25 mm/rev, depth of cut 0.2, 0.4, 0.6 mm. The mined data can be useful for reduce surface roughness and tool wear, improving the overall quality of the machined parts. Surface finish is highly asked in manufacturing components as it effect on performance and production values. CNC machines used with minimum operator input. Important parameters considered for study were cutting speed, feed, depth of cut, and nose radius. finally, the author considered that cutting speed, feed rate should be considered for good SR, tungsten carbide inserts on the CNC machine shall be carried out. The values wanted of cutting speed, feed, depth of cut, and nose radius were determined for minimizing surface roughness, maximize tool life, and achieving both objectives simultaneously for effective and commercial turning of composition.

Muhammad Abas el.at.,[7] discusses the use of the lowest quantity lubricant (MQL) for machining aluminium alloy 6026-T9.The study conducted by adjusting machines at cutting speed 500 m/min, feed rate 0.3 mm/rev, depth of cut 2 mm. The feed rate observed that the most significant parameter for surface roughness. The study uses composite desirability function and criteria importance through inter-criteria (CRITIC) to optimize cutting parameters and measure surface roughness, tool life, and material removal rate. Ideal parametric requirements for dry and MQL environments are the same and for material removal rate and tool life feed rate and cutting speed was the most important parameters. For the research surface roughness was the main research area. The mined knowledge contains SEM and EDX analysis to give a material perspective analysis of the machined surface. At the stop, author concludes that both dry and MQL conditions showed that the most significant cutting performance for SR profile is feed rate.

M. C. Santos et.al.,[8] added further for the experiment AL1350-0 and AL7075-T6 was the base metal and added 12% Sic to get results of composition. The machining force and CTR decreased with an increase in cutting speed and increased with higher feed rate and depth of cut. The results indicated that all input parameters significantly affected the responses. While the experiment considered cutting speed -1.41, -1, 0.1 m/min, feed rate 0, -1, -1 mm/rev, depth of cut 0, 1, 0, 1 mm. The study aimed to investigate the effects of crucial performance parameters like machining force, chip thickness ratio (CTR), and high-strength aluminium alloys at different cutting conditions using a central composite design of experimental setup. High-strength materials like ferrous, nickel, and titanium alloys lead to high tool wear and low surface integrity, while for less resistant and more ductile materials like aluminium, cutting forces, chip formation, and disposal are crucial output parameters. The machining forces of aluminium alloys increased at lower speed conditions, particularly for the more ductile 1350-O alloy, resulting in higher CTRs due to thicker chips being produced. machining forces increase due to reduction of heat generated. Deeper cuts also increased the difficulty of controlling chips.

P. Jayaraman et.al.,[9] Given a new approach for optimizing machining parameters in the turning of AA 6063-T6 aluminium alloy as the base metal and mixed the 0.6% sic, 0.34% Fe, 0.09% Cu, 0.095Mn, 0.88% Mg, 0.092% Cr, 0.95% Zn , 0.092% Ti etc. The method uses grey relational analysis to suit the cutting speed, feed rate, and depth of cut sets the parameters to value respectively. cutting speed 119.22, 158.96, 198.71 m/min, feed rate 0.05, 0.075, 0.1 mm/rev, depth of cut 0.1, 0.25, 0.2 mm. Selecting the right input parameter and turning is the crucial process in today's manufacturing industry. The study took some responses, including surface roughness, roundness, and material removal rate as the performance parameter. At the end the author comes to know that, the best multiple performance characteristics were obtained with an uncoated insert. The Taguchi method of parameters is valued for turning off the AA 6063-T6.

S.Sivasankaran et.al.,[10] The machinability of in-situ metal matrix composites made of AA7075 as a base metal and reinforcement 1 % ZrB2 was investigated in terms of the effect of graphite addition and tool nose radius. Increasing the nose radius led to decreased surface roughness, with optimal results achieved with a cutting speed 125, 150 m/min, feed rate 0.075, 0.15, 0.225 mm/rev, depth of cut 0.5, 1, 1.5 mm nose radius 0.4mm and SR, machining properties was the performance parameter so Decreasing the feed rate and depth of cut increased surface finish. Finally, the author comes to know that, Chips formed were continuous with no serrations when using a 0.8 mm nose radius. the results show that a 0.8 mm nose radius inserted tool and a combination of higher cutting speed, lower feed rate, and lower depth of cut produced excellent machinability, The nose radius of the tool increases SR of the work piece and decreases surface fining without burr.

K. Palanikumar et.al.,[11] taken LM25 Al as the base metal and added sic 10, 15, 25% as the reinforcement each. Optimal machining conditions for maximizing metal removal rate and minimizing surface roughness were determined using response surface methodology. For experimental setup took input parameters as, cutting speed 50, 100, 150 m/min, feed rate 0.20, 0.40, 0.60 mm/rev, depth of cut 0.5, 1.5, 2.5 mm. And further added the performance parameters as, Surface roughness as well as the matrix properties, all affect the cutting process. The present investigation used Taguchi's experimental design techniques to study. Finally, the author's result reveals Significant improvement can be achieved in composite turning operations by maximizing metal removal rate (MRR) and minimizing surface roughness and good surface roughness has been achieved.

K. Palanikumar et.al.,[12] took A356 for composition and SiC 20% added to the base metal A356,Showing a high strength-to-weight ratio, stiffness at elevated temperatures, and good wear resistance, this material offers a lower cost alternative to monolithic alloy. Machining MMC composites is quite difficult due to the multiplying of hard and stiff reinforcing materials and volume fraction of the reinforcement phase affects the all cutting process. For the machining took parameter as mentioned further, cutting speed 75, 125, 175 m/min, feed rate 0.1, 0.2, 0.3 mm/rev, depth of cut 0.5, 1, 1.5 mm. Diamond coated tool played the big roll to improve the overall life of the tool and whole setup was done for achieving good SR. While SR was the performance parameter over there. Max cutting speeds minimize the surface roughness and higher feed increases it too. At the end the author comes to the point, optimal conditions reduce the SR in machining.

E. Kılıc¸kap et.al.,[13] took Aluminium as a base metal and mixed 5% Sic. for the operations he sat up value of input parameter as cutting speed 50, 100, 150 m/min, feed rate 0.1, 0.2, 0.3 mm/rev, depth of cut 0.5, 1, 1.5 mm and cutting medium was dry.He had taken performance parameters like cutting speed and tool wear for his study. tool wear becomes greater with increasing cutting speed and was declined when used coated cutting tools. cutting speed, tool wear was the focused area of the study. Surface roughness has an effect on, by cutting speed and feed rate, with higher cutting speeds and lower feed rates getting better surface quality. Finally, the author added in his study that, build up edge formation was unseen and tool wear increased. TiN coated cutting tools are suggested for higher performance.

Ashok Kumar.m.s.et.al.,[14] used the stir casting method to add sic0.7%, fe 0.6%, cu 0.30%, zn0.10%, ti 0.10%, mn 0.05% into aluminium 6061. While the experiment state was adjusted as a semi liquid state. For the machining process sat up the parameters as further, cutting speed 140, 310, 500 m/min, feed rate 2, 2.5, 3.75 mm/rev, depth of cut 0.5 mm . Cutting forces was the focused area of the author. there is no decrease in cutting force with an increase in speed. The HSS tool experiences higher cutting forces when the cutting speed and feed rate are increased. At the end authors come to the result is, getting higher cutting speed does not result in a decline of cutting forces. The work material couldn't soften due to getting valued in interface temperature. Tool wear leads to higher cutting forces.

A.K Sahoo. et.al.,[15] took AL base metal and added 10% SiCp For experimental composition has been done conventional casting process. Under dry environment by considering the Taguchi’s theory. while the machining chips formed by putting dry environment. Colour of chips change from metallic to slightly blue. For this condition author assumed the input parameters as cutting speed 60,120,180 feed rate 0.05, 0.1, 0.15 depth of cut 0.2, 0.3, 0.4 and performance parameters was surface roughness. he observed that SR increased by increasing feed value. Finally, he added that minimum tool wear and good SR can be achieved by using multiple layers of TiN coated carbide insert.

S. Prakashrao Patil et al; [16] summarized the effects of adding various types and sizes of reinforcements into aluminium based alloys. They have compared the effect of various machining parameters viz. cutting speed, feed, depth of cut on response parameters viz. microstructure, surface roughness, MRR etc. He found that there are many authors who have added SiC as a reinforcement but very few have added graphene as a reinforcement.

III. CONCLUSION

1. Experimental study and optimization models can be useful for aerospace industries in the face milling of aluminium composites reinforcement with B4C and SiC.
2. Addition of TiB2 up to 5% leads to porosity and affects hardness.
3. Addition of different reinforcement into base metal requires an appropriate tool for machining otherwise it leads to burr formation and chips formation.
4. It is revealed that feed rate and depth of cut are prominent factors which affect the turning of aluminium alloy. As the feed rate and depth of cut decreases the surface finish increases with increasing cutting speed.
5. Uncoated carbide insert gives best result at lower cutting speed 119.22 m/min. lower feed rate of 0.05 mm/rev and medium depth of cut 0.15.
6. Almost all researchers took SR as a performance parameter for their study but castability, porosity and forces required for cutting and motion of object should be considered. Common reinforcement was SiC but graphene, carbon fiber should be added in list.

IV. FUTURE SCOPE

Till now, mostly SiC was considered as a reinforcement but for the future we can study in carbon fiber and waste material. considering thermal resistivity and safety factor carbon fiber would be the best reinforcement.

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REFERENCES

[1]. Johny James.S., Venkatesan.K., Kuppan.P., Ramanujam.R, "Hybrid Aluminium Metal Matrix Composite Reinforced With SiC and TiB2," Procedia Engineering 97 (2014), 1018 – 1026

[2]. Karabulut, Ş., Gökmen, U. &Çinici, H, "Optimization of Machining Conditions for Surface Quality in Milling AA7039-Based Metal Matrix Composites". Arab J Sci Eng 43, 1071–1082 (2018), https://doi.org/10.1007/s13369-017-2691-z

[3]. Richard J TLin, DebesBhattacharyya, "Machinability of a silicon carbide reinforced aluminium metal Matrix composite", Wear 181-183 (1995), 883-888, DOI:10.1016/0043-1648(95)90211-2

[4]. M. Ramulu., P.N. Rao., H. Kao."Drilling of (Al2O3)p/6061 metal matrix composites." Journal of Materials Processing Technology, Volume 124, Issues 1–2, 10 June 2002, 244-254, https://doi.org/10.1016/S0924-0136(02)00176-0

[5]. Ajithkumar J P., and Anthony., Xavior m, "Cutting Force and Surface Roughness Analysis During Turning of Al 7075 Based Hybrid Composites." Procedia manufacturing 30 (2019) 186-187

[6]. Rajesh Kumar Bhushan. "Multi-Response Optimization of Parameters during Turning of AA7075/ SiC Composite for Minimum Surface Roughness and Maximum Tool Life." Springer Nature B.V. 2020

[7]. Muhammad Abas, Lal Sayd, Rehman Akhtar, Qazi Salman Khalid, Aqib Mashood Khan, Catalin Iulian Pruncu, "Optimization of machining parameters of aluminum alloy 6026-T9 under MQL-assisted turning process." j mater res technol . 2020;9(5):10916–10940

[8]. M. C. Santos Jr, A. R. Machado , M. A. S. Barrozo , M. J. Jackson & E. O. Ezugwu "Multi-objective optimization of cutting conditions when turning aluminum alloys (1350-O and 7075-T6 grades) using genetic algorithm." Int J Adv Manuf Technol DOI 10.1007/s00170-014-6314-5

[9]. P. Jayaramana, L. Mahesh kumar. "Multi-response Optimization of Machining Parameters of Turning AA6063 T6 Aluminium Alloy using Grey Relational Analysis in Taguchi Method." Procedia Engineering 97 (2014) 197 – 204

[10]. S.Sivasankarana, P.T.Harisagar, E.Saminathan, S. Siddharth, P.Sasikumar. "Effect of nose radius and graphite addition on turning of AA 7075ZrB2 in-situ composites." Procedia Engineering 97 (2014) 582 – 589

[11]. K. Palanikumar& R. Karthikeyan, "Optimal machining conditions for turning of particulate metal matrix composites using taguchi and response surface methodologies", Machining Science and Technology: An International Journal, 10:4, 417-433, DOI: 10.1080/1091034060099 Engineers

[12]. K. Palanikumar , N. Muthukrishnan& K. S. Hariprasad. "Surface roughness parameters optimization in machining a356/ sic/20p metal matrix composites by pcd tool using response surface methodology and desirability function." Machining Science and Technology: An International Journal, 12:4, 529-545

[13]. E. Kılıc¸kap,O.C ¸ akıra, M. Aksoy ,A.˙Inan, "Study of tool wear and surface roughness in machining of homogenised SiC-p reinforced aluminium metal matrix composite." Journal of Materials Processing Technology 164–165 (2005) 862–867

[14]. Ashok Kumar, "Machinability Study of Aluminium Metal Matrix Composite (Al6061 -SiC)", Journal of fluid mechanics and mechanical design, (2020) 1-10,DOI: 10.5281/zenodo.3786119

[15]. A.K. Sahoo,n, S. Pradhan, A.K. Rout. "Development and machinability assessment in turning Al/SiCp-metal matrix composite with multilayer coated carbide insert using Taguchi and statistical techniques." archives of civil and mechanical engineering 13 (2013) 27–35

[16]. Suhas Prakashrao Patil, Sandeep Sadashiv Kore, Satish Suresh Chinchanikar, & Shital Yashwant Waware. Characterization and Machinability Studies of Aluminium-based Hybrid Metal Matrix Composites – A Critical Review. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 101(2), 137–163, (2023), https://doi.org/10.37934/arfmts.101.2.137163

[17]. S. Prakashrao Patil, G. Leela Prasad, C. Sai Kiran et al., Surface roughness and topography of EDM machining of Inconel 718, Materials Today: Proceedings,https://doi.org/10.1016/j.matpr.2023.02.444